Flight Crew Fatigue II: Short-Haul Fixed-Wing Air Transport Operations

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We monitored 74 crewmembers before, during, and after 3–4-d commercial short-haul trips crossing no more than one time zone per 24 h. The average duty day lasted 10.6 duty hours, with 4.5 flight hours and 5.5 flights. On trips, crewmembers slept less, woke earlier, and reported having more difficulty falling asleep, with lighter, less restful sleep than pretrip. The consumption of caffeine, alcohol, and snacks increased on trip days, as did reports of headaches, congested nose, and back pain. The study suggests the following ways of reducing fatigue during these operations: base the duration of rest periods on duty hours as well as flight hours; avoid scheduling rest periods progressively earlier across a trip; minimize early duty report times; and inform crewmembers about strategic use of caffeine and alternatives to alcohol for relaxing before sleep.

IN THE 1980's, the Fatigue Countermeasures Program at NASA-Ames conducted a series of field studies to assess flight crew fatigue in a variety of aviation environments. The first of these studies looked at commercial short-haul air transport operations. This environment is characterized by predominantly daytime flying with multiple flight segments crossing few, if any, time zones per day. The schedules were thus expected to cause minimal disruption to the circadian clock, because they allowed crewmembers to sleep during local night and did not require adaptation to new time zones. In this respect, they were viewed as a type of baseline condition against which to compare the subsequent studies of operations involving night work (overnight cargo) and irregular shift work with transmeridian flying (long-haul operations). However, short-haul operations also have specific characteristics which have been identified as potential causes of fatigue, namely long duty days with multiple flight segments and relatively long periods on the ground between flights.

Since take-off and landing are the phases of flight with the highest workload and potential for accident (15), multiple take-offs and landings in a day might be expected to have cumulative effects on fatigue and performance. Ruffell-Smith (21) reported increases in heart rate during take-off, approach, and landing of captains flying commercial Trident aircraft on selected short-haul flights. On this basis, he recommended that the number of daily flight segments should be included as a factor

in the design of flight crew schedules. In a preliminary study of the effects of fatigue on flying proficiency (with one subject), Howitt et al. (11) reported behavioral observations indicating that fatigue produced by repeated flights on the same day was characterized by boredom and a lack of concern about maintaining precision on instruments.

Flying several multi-segment duty days consecutively might also be expected to have cumulative effects on fatigue and performance. Klein et al. (12) monitored physiological indices of acute stress in 11 B-737 crews across two different 3-d trips involving either a 0600–1400 hours or a 1200–2300 hours schedule. There was no evidence for cumulative effects of successive days of flying on in-flight increases in pulse and respiration rates, or on increases in urinary concentrations of catecholamines and 17-OHCS during duty days.

If long duty days and short nighttime layovers reduce the amount of sleep that crewmembers are able to obtain on trip nights, then cumulative effects on alertness and performance would be expected. In the laboratory, reducing sleep by as little as 1 h per night increases daytime sleepiness, and the effects of successive nights of reduced sleep accumulate (4,5). Reducing sleep by 2 h per night can impair alertness and performance, and causes changes in sleep architecture (shorter sleep latencies, deeper sleep, and fewer awakenings) which signal insufficient sleep (5).

Currently, Federal Aviation Regulations (FARs), which are in the process of being revised, specify scheduled rest times according to the number of hours flown in the preceding duty day. These rest times can be reduced when unforeseen circumstances arise that are beyond the company's control (aircraft malfunctions, adverse

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Flight	Scheduled Rest	Can Be Reduced To	Compensatory Next Rest Period
<8	9 h	8 h	10 h
8–9	10 h	8 h	11 h
>9	11 h	9 h	12 h

weather, etc). In such cases, a mandated longer rest period must begin within 16 h after the reduced rest period. The requirements for Part 121 domestic operations (FAR 121.47), which governed the short-haul operations studied, are summarized in **Table I.**

There is currently no allowance made for the time of day when duty takes place. The rest time required by the FARs begins when a crewmember comes off duty and ends when he or she goes back on duty (i.e., it can include the time for traveling to and from home or a layover hotel). The FARs serve as guidelines within which individual companies decide their own scheduling policies by negotiation between management and pilots.

Two commercial airlines participated in the field study of fatigue in short-haul fixed-wing operations. The most challenging 3–4 d trips being flown by these companies were selected for study from the monthly bid packages. Most flights remained in the eastern U.S., but some crossed one time zone to central U.S.. All trips included considerable time in high traffic-density airspace.

METHODS

The 37 captains and 37 first officers (all male) who volunteered to participate were flying B-737 or DC-9 aircraft. They were monitored before, during, and after the trips summarized in **Fig. 1.** Between consecutive duty days, crews stayed in en-route layover hotels. Data were collected across all seasons of the year and were recorded on Greenwich Mean Time (GMT). They were converted to local time where necessary in the analyses (Eastern Standard Time, EST = GMT-5 h; or Eastern Daylight Time, EDT = GMT-4 h).

Characteristics of the trips are summarized in **Table II.** Data for duty times and layover durations were taken from the daily logbooks kept by crewmembers. Data for flight hours, number of segments, and segment duration were from the cockpit observer logs (9).

As expected, the number of flight hours per day was less than the number of duty hours per day. This difference was significant (matched pairs t-test, $t = -58.46$, p < 0.0001). About one third (32%) of all duty days were longer than 12 h. The mean rest period reported by crewmembers in their daily logs (12.5 h) was shorter than the time from last wheels-on at the end of one duty day to first wheels-off at the beginning of the next duty day (14.0 h; matched pairs t-test, $t = -17.52$, p < 0.0001). **Fig. 2** illustrates that, on average, duty days began and ended progressively earlier across trips. Two-way ANOVAs (trip-type by days-of-trip) revealed that this trend was significant for on-duty times (F = 3.24, 0.05 > p > 0.01) and for off-duty times (F = 7.75, p < 0.001).

To be included in the analyses, crewmembers had to have provided complete logbook data for at least one pretrip day, all trip days, and at least one posttrip day. There were 44 crewmembers who provided sufficient data, including 11 for whom data from the second and third days posttrip were used as baseline. Their average age was 43.0 yr (SD ± 7.7) and they flew an average of 70.2 h (SD ± 9.9) per month in all categories of aviation. They had an average of 17.1 yr (SD ± 6.6) of airline experience. Unless otherwise stated, all analyses of variance were within subjects. For t-tests, where a Levene's test revealed unequal variances, the separate t-test value was taken. Otherwise, the pooled t-test value was taken.

In addition to the logbook fatigue measures, changes in heart rate during different phases of flight were also examined. Since the physiological monitor recorded only 2-min averages of the r-wave intervals, it was not possible to examine beat by beat variability. The heart rate during take-off was taken as the average of three consecutive 2-min intervals, with actual take-off occurring in the first 2-min interval. The heart rate during mid-cruise was taken as the average of five consecutive 2-min intervals centered between top-of-climb and top-of-descent. The heart rate during descent was taken as the average of five consecutive 2-min intervals, with touch-down occurring in the 2-min interval immediately following the 10 min defined as descent. The average heart rate during landing was taken as the average of three consecutive 2-min intervals, with touch-down occurring in the last interval. Complete heart rate data were available for 589 flight segments. For each flight segment for each crewmember, the heart rate during mid-cruise was subtracted from the heart rates during take-off, descent, and landing. These differences were then expressed as percentages of the heart rate during mid-cruise. The percentage change in heart rate was chosen as a metric to minimize inter-subject and time-of-day variability.

RESULTS

Sleep

Table III compares the average sleep measures on pretrip, trip, and posttrip nights. Sleep latency was calculated as the difference between the reported times of going to bed and falling asleep. Scores on the four sleep quality questions, rated from 1 (least) to 5 (most), have been converted so that higher values indicate better sleep, and combined to give the overall sleep rating. Heart rate and activity data during each sleep episode have been trimmed to include values from 20 min after the reported sleep onset time until 10 min before the reported wakeup time (9). Only 11 of 44 crewmembers provided sufficient physiological data for these analyses. In this first field study, most data loss occurred because of technical or logistical difficulties. The probabilities in Table III indicate values for pretrip/trip/posttrip comparisons in one-way analyses of variance (ANOVA) with subjects treated as a random variable. When an ANOVA was significant, pretrip, trip, and posttrip values were compared by post hoc t-tests. All the comparisons described below were significant at least at p < 0.05.

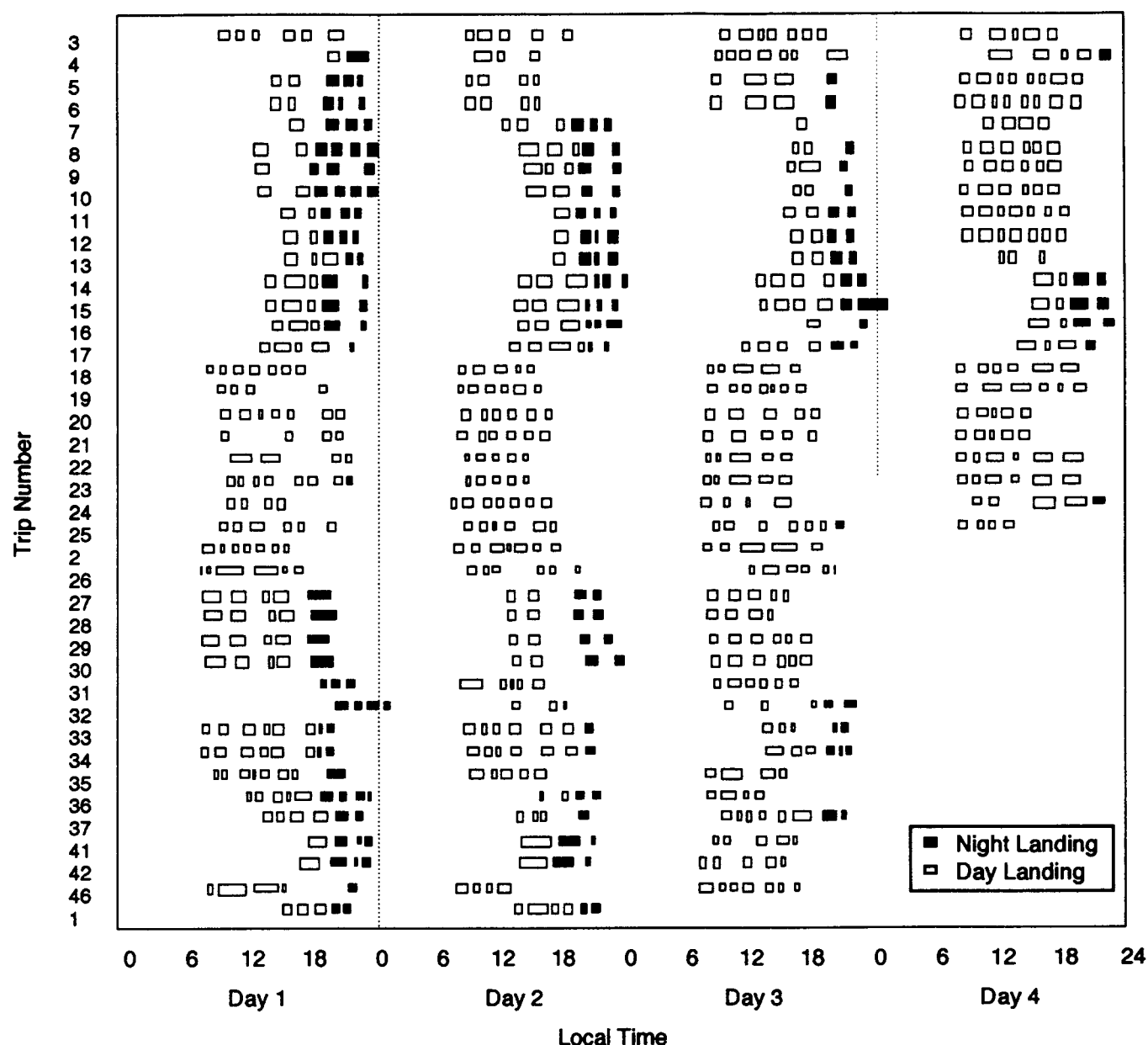On trips, crewmembers slept less, awoke earlier and reported having more difficulty falling asleep, with

Fig. 1. Sequence of flight segments for each of the trips studied (23 4-d trips; 16 3-d trips; 1 preliminary 2-d trip which was not included in the analyses). Trip numbers indicate the order in which trips were studied. Open boxes: segments landing in daylight. Black boxes: segments landing at night.

lighter, less restful sleep, and poorer overall sleep quality, than either pretrip or posttrip. The analyses in Table III include the final sleep episode prior to the trip as a pretrip sleep episode. However, crewmembers were frequently required to get up earlier than usual to report for duty on the first day of the trip. Considering this sleep episode as a trip sleep suggests that, in addition to the differences in Table III, crewmembers also took longer to fall asleep on trip nights (mean 24.7 min) than pretrip (mean 15.7, F = 7.75, p < 0.001). The total sleep per 24 h calculated this way was shorter on trip days (mean 6.6 h) than either pretrip (mean 8.2 h) or posttrip (mean 7.7 h, F = 22.55, p < 0.001).

The percentage of subjects who reported sleeping or napping more than once per 24 h was particularly low

on trip days (pretrip 21%, trip 7%, posttrip 15%). This may be the result of long duty days and relatively short nighttime layovers (Table II). Since the total sleep per 24 h (including all sleeps and naps) on trip days was 1.6 h shorter than during pretrip, crewmembers accumulated a sleep debt across trips (**Fig. 3**). Comparing trip days to pretrip days, 67% of crewmembers averaged more than 1 h of sleep loss per 24 h, and 30% averaged more than 2 h of sleep loss. The hours of sleep lost during the trips were not regained after 2 nights of posttrip sleep (the curves in Fig. 3 do not return to zero). However, this is not unexpected since sleep loss is normally compensated by deeper rather than proportionally longer sleep (7).

Crewmembers on 3-d trips averaged significantly more sleep loss per day than did crewmembers on 4-d

TABLE II. TRIP STATISTICS.

	Mean (SD)	Minimum	Maximum
On-duty (local time)	0943 (4.19)	0500	2115
Off-duty (local time)	1930 (2.86)	0935	0130
Duty hours/day	10.63 (2.24)	2.23	15.83
Flight hours/day	4.51 (1.35)	0.83	7.48
(Duty-Flight) hours	6.13 (1.68)	0.29	10.72
# Segments/day	5.51 (1.37)	1.00	8.00
Segment duration (h)	1.07 (0.46)	0.22	2.97
Nighttime layover (h)	12.45 (2.66)	7.17	20.02

Note: Trips crossed no more than one time zone in 24 h.

trips (paired t-test, $t = 4.24, 0.001 > p > 0.0001$). Part of this difference may be an artifact of the way that sleep loss was calculated. Three-day crewmembers were three times more likely to nap on the day before a trip. This napping extended their total baseline sleep beyond what they reported in the Background Questionnaire as their usual amount of home sleep (matched pairs t-test, $t = 2.41, 0.05 > p > 0.01$), which suggests that it may have represented a strategy to cope with anticipated sleep loss. These pretrip naps inflated the estimate of baseline sleep duration, against which subsequent sleep loss was calculated. Duty days on 3-d and 4-d trips were of comparable length. However, 3-d trips included significantly more daily flight hours than did 4-d trips (two-way ANOVA, trip-type by days-of-trip; F for the trip-type comparison = 7.40, $0.01 > p > 0.001$). Thus there was less time available for napping between flight segments on 3-d trips.

Fatigue and Mood Ratings

Every 2 h while they were awake, crewmembers rated their fatigue level on a 10 cm line from"most alert" to "most drowsy." They also rated their current mood from 0 (not at all) to 4 (extremely) on 26 adjectives which were found to load on three orthogonal factors: positive affect, negative affect, and activation (8). Within subjects two-way ANOVAs (pretrip/trip/posttrip by time-of-day) were carried out to see if duty demands had a measurable effect on fatigue and mood ratings (Table IV). There were 11 crewmembers who provided sufficient data for these analyses, with the ratings grouped in 4-h time bins. Fatigue, negative affect, and activation showed sig-
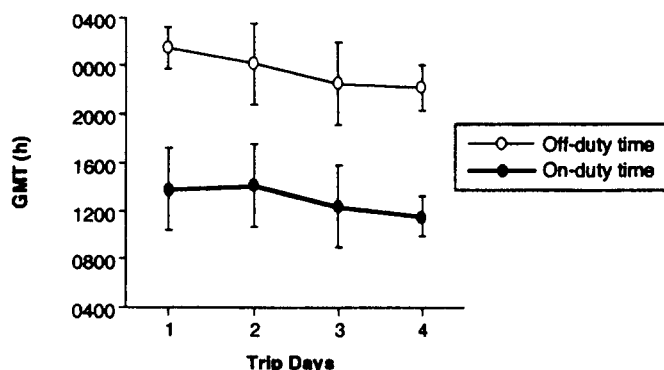
TABLE III. COMPARISONS OF SLEEP MEASURES BEFORE, DURING, AND AFTER TRIPS.

	Pretrip	Trip	Posttrip	F
Sleep onset (GMT)	4.39	4.17	4.55	4.08*
Wakeup (GMT)	11.99	10.87	12.17	31.38***
Sleep latency (min)	23.50	25.60	22.73	0.32
Sleep duration (h)	7.22	6.59	7.36	6.33**
Total sleep/24 h	7.39	6.68	7.55	7.73*
Difficulty falling asleep?	4.34	3.95	4.30	4.00*
How deep was your sleep?	3.84	3.22	3.77	15.41***
Difficulty rising?	4.06	4.11	3.94	1.00
How rested do you feel?	3.47	3.08	3.42	4.07*
Sleep rating	15.70	14.34	15.42	6.24**
# Awakenings	1.20	1.15	1.14	0.29
Mean heart rate (bpm)	63.33	64.41	61.50	1.45
S.D. heart rate	6.65	7.21	7.05	0.13
Mean activity (counts/min)	1.29	1.35	1.39	0.04
S.D. activity	4.46	5.15	5.46	0.23

* $0.05 > p > 0.01$; ** $0.01 > p > 0.001$; *** $p < 0.001$.

nificant time-of-day variation (Fig. 4). However, these analyses suggests that none of the ratings changed significantly across trip days by comparison with pretrip or posttrip.

In order to include data from a larger number of crewmembers (n = 34), a one-way ANOVA, treating subjects as a random variable, was carried out to compare the final ratings of the day on pretrip, trip, and posttrip days (Table V). The only significant change was that positive affect was lowest posttrip.

Caffeine and Alcohol Consumption

Caffeine was available in-flight as well as on the ground. The number of cups of caffeinated beverages,

Fig. 2. Average on-duty and off-duty times across trips (vertical lines indicate standard errors).
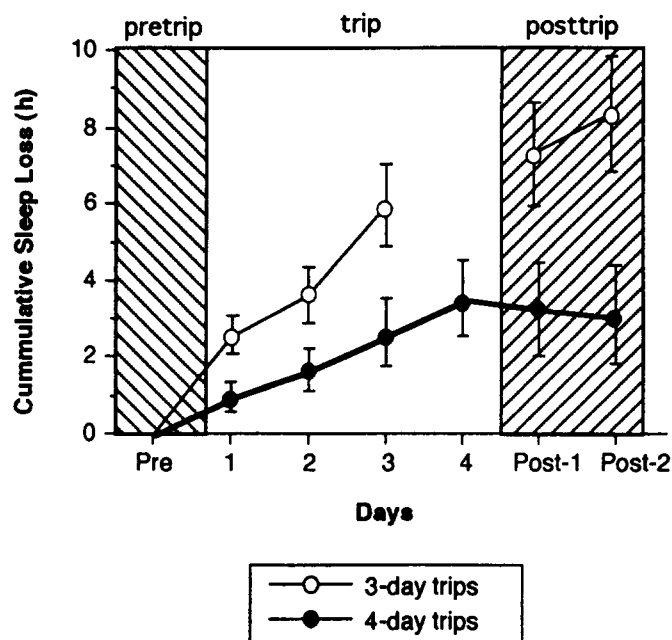

Fig. 3. Average cumulative sleep loss with respect to baseline sleep, across 3-d and 4-d trips. For each subject, his total sleep per 24 h on each trip day was subtracted from his average total sleep per 24 h on pretrip days, to give a daily measure of sleep loss. Average daily sleep loss was then calculated, and the values added across the consecutive trip days and posttrip days. Vertical lines indicate standard errors.

TABLE IV. FATIGUE AND MOOD RATINGS ACROSS PRETRIP, TRIP, AND POSTTRIP DAYS.

	F Pre/Trip/Post	F Time-of-Day	F Interaction
Fatigue	0.60	4.49*	1.31
Positive affect	1.43	1.34	0.33
Negative affect	1.25	13.90***	1.25
Activation	2.45	15.42***	1.11

* $0.05 > p > 0.01$; *** $p < 0.001$.

TABLE V. FINAL FATIGUE AND MOOD RATINGS OF THE DAY, COMPARING PRETRIP, TRIP, AND POSTTRIP DAYS.

	Pretrip Mean (SD)	Trip Mean (SD)	Posttrip Mean (SD)	F
Fatigue	52.7 (15.0)	52.9 (12.1)	58.6 (16.7)	2.75
Positive affect	2.29 (0.62)	2.24 (0.52)	2.02 (0.70)	4.19*
Negative affect	0.79 (0.56)	0.80 (0.39)	0.88 (0.43)	0.92
Activation	1.56 (0.64)	1.75 (0.54)	1.52 (0.66)	2.71

* $0.05 > p > 0.01$.

and the time of day at which they were consumed, were recorded in the daily logbook. Alcohol consumption was also indicated, with one glass of beer or wine, or one measure of spirits, counting as one serving. Since Federal Regulations prohibit the consumption of alcohol within 8 h of going on duty, it is assumed that alcohol consumption on trip days took place in the evening, after coming off duty.

Caffeine was consumed at some time during the study by 94% of the crewmembers, while alcohol was consumed by 73%. To test if duty demands had an effect on caffeine or alcohol consumption, one-way ANOVAs were performed, with subjects treated as a random variable **(Table VI)**.

Caffeine consumption increased during trips by comparison with pretrip levels ($t = 3.92$, $p < 0.001$). Alcohol consumption also increased during trips by comparison with pretrip ($t = 4.55$, $p < 0.0001$) or posttrip ($t = 1.98$, $0.05 > p > 0.01$).

Meals and Snacks

Only one of the two participating airlines provided crew meals in flight. The time of eating and classification of meals (breakfast, lunch, dinner, snack) was recorded in the daily logbook. To test whether duty demands had an effect on the number of meals or snacks eaten per day, one-way ANOVAs were performed with subjects treated as a random variable **(Table VII)**.
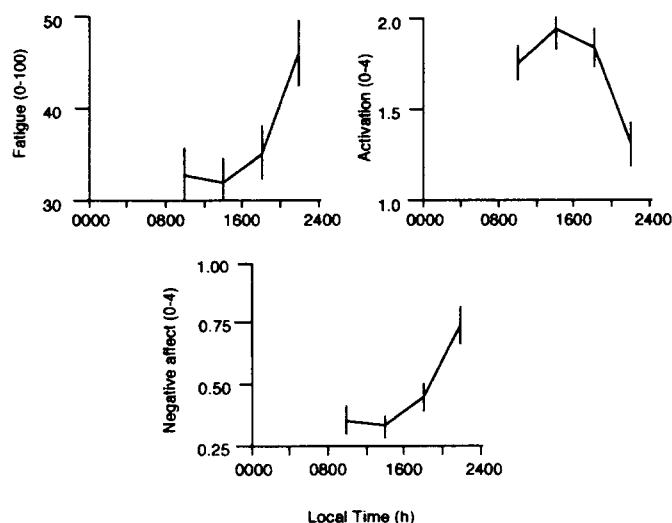
More snacks were eaten on trip days than either pretrip ($t = 9.30$, $p < 0.0001$) or posttrip ($t = 3.91$, $0.001 > p > 0.0001$). To test if the provision of crew meals affected the number of meals or snacks eaten, two-way ANOVAs (company by pre/trip/post) were performed **(Table VIII)**.

These analyses suggest that the provision of crew meals did not have a significant effect on the number of meals or snacks eaten. However they do not address the quality of the nutrition obtained.

Physical Symptoms

The logbook also contained a table for each day for noting physical symptoms (9). Some 60% of crewmembers indicated that they experienced at least one of the 20 categories of symptoms at some time during the study. The three most common symptoms were: headache (reported by 27% of crewmembers at some time during the study); congested nose (reported by 20% of crewmembers at some time during the study); and back pain (reported by 11% of crewmembers at some time during the study). The frequency of reports of each of these symptoms on pretrip, trip, and posttrip days is shown in **Table IX**. All three symptoms were reported most often on trips.

Heart Rate During Different Phases of Flight

Paired t-tests indicated significant increases in heart rate (compared with mid-cruise) during descent ($t = 5.48$, $p < 0.0001$) and landing ($t = 5.46$, $p < 0.0001$), but not during takeoff. In these operations, captains and first officers usually alternated cockpit seats, and thus responsibility for control of the aircraft, on successive flight segments. To test if changes in heart rate depended on rank (captain vs. first officer) or cockpit task (flying vs. not-flying) two-way ANOVAs were performed **(Table X)**.

During descent and landing, heart rate increased (by comparison with mid-cruise) for the crewmember flying (5.8% and 4.2%, respectively), but decreased slightly for the crewmember not flying (1.9% decrease and 0.1% decrease, respectively). During descent, the difference be-

Fig. 4. Time of day variations in fatigue and mood ratings (vertical lines indicate standard errors).

TABLE VI. CAFFEINE AND ALCOHOL CONSUMPTION.

	Pretrip	Trip	Posttrip	F
Caffeine, servings/day	2.03	3.06	2.60	8.78***
Alcohol, servings/day	0.34	1.54	0.90	14.16***

*** $p < 0.001$.

TABLE VII. CONSUMPTION OF MEALS AND SNACKS.

	Pretrip	Trip	Posttrip	F
Number of meals/day	2.38	2.33	2.40	0.123
Number of snacks/day	0.17	1.33	0.73	26.17***

*** p < 0.001.

TABLE IX. FREQUENCY OF REPORTS OF COMMON PHYSICAL SYMPTOMS.

Symptom	% Pretrip	% Trip	% Posttrip
Headache	32	41	27
Congested nose	26	58	16
Back pain	17	75	8

tween flying and non-flying conditions was greater for first officers (9.6%) than for captains (5.9%).

To test whether flight conditions affected heart rate changes, a two-way ANOVA was performed [visual flight conditions (VFR) vs. instrument flight conditions (IFR), and flying vs. not flying; **Table XI**].

During takeoff and descent, heart rate increases (by comparison with mid-cruise) were greater under IFR conditions (1.2% and 4.3%, respectively) than under VFR conditions (−0.6% and 1.6%, respectively). During descent, the difference between flying and not flying was greater under IFR conditions (11.0%) than under VFR conditions (7.2%).

DISCUSSION

This study is the first extensive documentation of sleep, circadian rhythms, and subjective fatigue during scheduled short-haul operations. On trip nights, the average sleep episode was about an hour shorter than on pretrip nights. Multiple regression analyses reported elsewhere (8) suggest that this was primarily due to long duty days, short nighttime layovers, and having to wake up over an hour earlier to report for duty. Sleep restriction caused by early on-duty times has also been reported in a study of USAF pilot instructors and students (16). Comparing the total sleep per 24 h (including naps) on trip days vs. pretrip days, 67% of crewmembers averaged more than 1 h of sleep loss on trip days, and 30% averaged more than 2 h of sleep loss. In the laboratory, 1 h of sleep loss per night produces a cumulative increase in sleepiness (4). Reducing nighttime sleep in the laboratory by more than 2 h can impair performance and cause changes in sleep architecture that indicate insufficient sleep (5). On the other hand, 12% of crewmembers reported averaging more sleep on trip nights than pretrip.

Average daily sleep loss was greater across 3-d trips than across 4-d trips. However, part of this difference may have been an artifact of the way sleep loss was calculated. Many 3-d crewmembers took a nap the day before going on duty. This nap inflated the estimate of baseline sleep duration, thereby increasing the apparent sleep loss on trip nights. The 3-day trips also included more flight hours per day than the 4-d trips. This would have limited the time available for napping on duty days.

Crewmembers did not compensate for early duty report times by going to sleep earlier on trip nights. Anecdotally, they often talked about needing to "spin down" (relax) after a duty day before being able to fall asleep. There are also physiological factors which make it difficult to fall asleep earlier than usual. Sleep onset is less likely at certain phases of the circadian cycle (the so-called "wake maintenance zones"), one of which occurs shortly before the habitual bedtime (23,24). In addition, because the "biological day" dictated by the circadian clock tends to be longer than 24 h, it is easier to go to sleep later than to go to sleep earlier. Going to sleep later also means staying awake longer, which allows more time for homeostatic "sleep pressure" to build up (2,7).

In addition to sleeping less on trip days, crewmembers also reported taking longer to fall asleep, and having lighter and less restful sleep. In contrast, reducing nighttime sleep in the laboratory results in shorter sleep latencies, and deeper sleep with fewer awakenings (5). If sleep quality was indeed compromised during trips, as the subjective ratings suggest, then this would be expected to further reduce subsequent alertness and performance, in addition to the effects of sleep loss (20). Unfamiliar and/or uncomfortable layover hotel rooms could have contributed to a reduction in sleep quality, as could the consumption of alcohol close to bedtime (see below).

Subjective ratings of fatigue and mood did not change significantly on trip days by comparison with pretrip days. Fatigue and negative affect ratings varied in parallel across the day, being lowest around noon and highest in the last rating of the day. This replicates the time-of-day variation in subjective fatigue ratings reported for people living under a variety of different experimental protocols (13,14,25). Activation ratings also varied significantly across the day, as the mirror image of fatigue and negative affect, being highest around noon and lowest in the last rating of the day. Subjective fatigue and activation ratings appear to be influenced by both the circadian cycle and the time since sleep (13,14). Positive affect did not show a significant time-of-day variation.

On trip days, crewmembers consumed 1.5 times more caffeine than on pretrip days. The additional caffeine was

TABLE VIII. MEALS BEFORE, DURING, AND AFTER TRIPS WITH AND WITHOUT CREW MEALS.

	F Company	F Pre/Trip/Post	F Interaction
Number of meals/day	0.65	2.03	0.13
Number of snacks/day	1.54	15.14***	0.11

*** p < 0.001.

TABLE X. HEART RATE CHANGES: EFFECTS OF RANK AND POSITION.

Phase of Flight	F Rank	F Flying/Not-Flying	F Interaction
Take-off	0.23	0.01	0.01
Descent	2.50	172.07****	9.61**
Landing	0.40	41.72****	0.71

** 0.01 > p > 0.001, **** p < 0.0001.

TABLE XI. HEART RATE CHANGES: EFFECTS OF WEATHER AND POSITION.

Phase of Flight	F VFR/IFR	F Flying?	F Interaction
Take-off	4.29*	0.16	0.31
Descent	8.22**	92.28****	3.94*
Landing	1.17	14.79****	0.07

* $0.05 > p > 0.01$, ** $0.01 > p > 0.001$, **** $p < 0.0001$.

consumed primarily shortly after wakeup (which was earlier on trips) and around the time of the mid-afternoon peak in physiological sleepiness (8). The urge to fall asleep in the afternoon would be expected to increase progressively with the sleep loss accumulating across trip days (4). Multiple regression analyses reported elsewhere (8) indicated that the earlier crewmembers went on duty, and the longer they remained on duty, the more caffeine they consumed. Caffeine can temporarily improve daytime alertness. However, consumed close to bedtime, it also has disruptive effects on sleep, including longer sleep latencies, lighter sleep, and more awakenings (3).

On trip days, crewmembers reported consuming 2.5 times as many alcoholic drinks as at home (combining pretrip and posttrip days). More alcohol was consumed after shorter duty days (8). Federal Regulations prohibit alcohol consumption within 8 h of going on duty, and it is assumed that drinking occurred after coming off duty in the evening. Alcohol consumed in close proximity to sleep causes dose-dependent changes in sleep, reducing the time taken to fall asleep but increasing the number of awakenings during sleep. It also suppresses rapid eye movement (REM) sleep in the first half of the night, leading to REM rebound in the second half of the night. Alcohol consumption and sleep restriction act synergistically to increase daytime sleepiness (3).

Crewmembers ate twice as many snacks on trip days as on pretrip and posttrip days. However, the number of meals eaten did not change. This might indicate that meals eaten on trip days were less filling. The provision of crew meals did not alter the number of meals or snacks eaten on trips. However, since meal content was not considered in these analyses, it would be premature to conclude that the provision of crew meals did not affect the quality of nutrition on trips.

Physical symptoms were reported by 60% of crewmembers at some time during the study, with the three most common symptoms being headaches, congested nose, and back pain. The incidence of reports of all three symptoms was greater on trips than at home.

During descent and landing, the responsibility of flying the aircraft produced significant increases in heart rate (over the level during mid-cruise). During descent, this effect was greater for first officers flying than for captains flying, and was exacerbated under instrument flight conditions. When instrument flight conditions prevailed during takeoff, heart rate increases were greater than under visual flight conditions. Similar effects have been observed in a wide variety of aircraft types, in line-flying, in line-training, and in simulators (1,10,11,17–

19,21,22). It has been argued that these heart rate responses in experienced pilots are influenced primarily by work-related factors, rather than emotional stressors such as risk and anxiety (17–19).

In summary, the trips studied required crewmembers to wake up earlier, thereby accumulating a sleep debt which, on the basis of laboratory studies, would be expected to reduce daytime alertness and performance. They also reported poorer quality sleep on trips. The consumption of caffeine, alcohol, and snacks increased on trip days, as did reports of headaches, congested nose, and back pain. The study suggests a number of ways in which these effects of trips could be improved.

1. In the trips studied, duty days were more than twice as long (average 10.6 h) as the total duration of the flights that they included (average 4.5 h). One third of the duty days were longer than 12 h. Longer duty days were not followed by proportionally longer rest periods (8). This suggests that one way of reducing sleep loss would be to include the duration of the duty day as a factor in the determination of the duration of the subsequent rest period. Current Federal Regulations base rest requirements entirely on flight hours.

2. The scheduling practice of requiring early report times makes it more difficult for crewmembers to obtain adequate sleep, even during relatively long layovers. This is because physiological factors tend to oppose falling asleep earlier than the usual bedtime. Minimizing early duty report times would thus be expected to reduce sleep loss. In the majority of the trips studied, duty also began and ended earlier on successive trip days. Because it is difficult to fall asleep earlier than usual, this has the effect of progressively reducing the time available for sleep in each successive layover. Thus, where possible, successive duty days should begin at the same time, or progressively later.

3. The use of alcohol as a means of relaxing before sleep appears to be widespread. While a "nightcap" may make it easier to fall asleep, it can have deleterious effects on sleep quality, and may therefore adversely affect subsequent alertness and performance. Sleep on trips could probably be improved in many cases by providing crewmembers with information on alternative relaxation techniques which have been well-tested in the treatment of sleep disorders.

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